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### Re

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## DEPARTMENTS

*Letters to the Editor***Was Hamstring Muscle Stiffness Measured?**

I commend Halbertsma et al<sup>1</sup> for their efforts to study the passive properties of the hamstring muscles of patients with low back pain. I do, however, have concerns about how stiffness of the hamstrings was measured and the conclusions that were based on this measurement.

Halbertsma calculated the passive hamstring moment (Nm) and represented the hamstring stiffness ( $M_{e-pas}$ ) as the maximal passive hamstring moment at the onset of integrated electromyographic activity during straight-leg raising. Based on this measurement, which was not significantly different among the 3 groups tested (flexible group [FG], stiff group [SG], patient group [PG]), the authors concluded that passive stiffness of the hamstrings did not differ. This conclusion appears to be invalid because passive stiffness was not measured. Instead, Halbertsma measured the maximal passive resistive torque (PRT), which is not the same as passive stiffness. Passive stiffness is a physiologic relationship of the change in the PRT ( $\Delta PRT$ ) in relation to a change in the angular displacement ( $\Delta Angle$ ). To measure passive stiffness, the authors would need to express passive stiffness by the  $\Delta PRT/\Delta Angle$ ,<sup>2,3</sup> or by other comparable units of passive resistance (ie, stress in  $Nm/cm^2$ ) and angular change (ie, radians).<sup>4</sup> For example, the  $\Delta PRT/\Delta Angle$  can be calculated at 1° intervals or averaged over multiple degrees as the muscles are stretched.<sup>2</sup> The PRT contributes to the passive stiffness, but the 2 properties are not synonymous.

Further inspection of the results indicates that the pelvic-femoral maximal angular displacement ( $\phi_{max}$ ) during straight-leg-raising was less for the PG ( $40.3^\circ \pm 10.41^\circ$ ) than for the SG ( $48.2^\circ \pm 6.69^\circ$ ) and the FG ( $55.0^\circ \pm 5.40^\circ$ ). If the PRT was measured from the onset of the movement (which appears possible from fig 4), then the average passive stiffness would be measured by dividing the maximal PRT by the total angular displacement. This may not have been true for all subjects, but is offered here to illustrate my concern. Simple calculations from table 2 reveal that the average passive stiffness ( $Nm/deg$ ) for the 3 groups would be: FG = .63, SG = .79, and PG = .87. This indicates that the average passive stiffness for the PG was greater than the average passive stiffness for the SG and the FG. Although these calculations would need to be confirmed, they suggest that the hamstrings of the PG may have been stiffer. Although the  $M_{e-pas}$  did not differ among groups, the decreased pelvic-femoral angular displacement for the PG would increase their average passive stiffness.

Again, I commend Halbertsma for the effort to study this interesting topic. I hope, however, that my comments help to clarify the meaning of their results, and that future investigations and reports include careful attention to the meaning of passive muscle stiffness.

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**References**

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**The authors reply**

Gajdosik mentions that, in his opinion, we were measuring maximal passive resistance torque instead of muscle stiffness. Our definition of stiffness is in agreement with Göeken and Hof,<sup>1</sup> and we have used this definition of muscle stiffness since 1991 in all our papers published in *Archives*. The pulling force necessary to lift the leg in straight-leg raising acts perpendicularly to the length axis of the leg at the ankle joint. The hamstrings muscle moment could be calculated from the pulling force and lever arm (lateral maleolus–trochanter major). We have defined the nonlinear passive muscle moment (corrected for gravity) as a function of angular displacement (pelvic-femoral angle) as muscle stiffness:  $M_e = f(\phi)$ . However, we are aware of the limitations. Also, in manually performed clinical stretch tests when describing properties of muscle resistance, mostly muscle stiffness is reported.

Lee and Munn,<sup>2</sup> for example, used the passive moment about the hip in straight-leg raising. So we think that other definitions can be used as long as they are properly defined and one is aware of the limitations. Measuring stiffness requires both cross-sectional area and change in muscle length. To compare muscle stiffness between individuals, we can evaluate the stress-strain curve. Measuring the cross-sectional area would make it possible to define stress or tension in  $Nm/cm^2$ . We measured the hamstrings cross-sectional area and muscle length of the patients with magnetic resonance imaging. Because the cross-sectional area is not constant and the muscle length not homogeneous, we did not use it for further calculations. When measuring the pelvic-femoral angle, one must also realize that equal angular rotation in different patients does not mean equal muscle elongation ( $\Delta l$ ) or muscle length ( $L$ ).

When measuring passive stiffness, it is necessary to check for activity of the hamstrings. In our article,<sup>3</sup> we reported about passive muscle stiffness at the instant of muscle activity. In table 2,  $\phi_{max}$  may be a bit confusing. It indicates the maximum pelvic-femoral angle and not the angle of onset of hamstring muscle activity. There was no significant difference in the onset of the I-EMG for subjects of the stiff group (SG) and flexible group (FG). The passive muscle stiffness also did not differ between SG and FG at that specific  $\phi_{EMG}$ . The onset of the I-EMG of the hamstrings of the patient group (PG) was

significantly earlier compared with the SG. Next, we compared the passive muscle stiffness for PG and SG at  $\varphi_{\text{EMG}}$  (the onset of I-EMG of the PG). It should be noted that  $\varphi_{\text{EMG}}$  between FG-SG and PG were not the same. Therefore the stiffness at  $\varphi_{\text{EMG}}$  between FG-SG and PG was also different.

We hope by this explanation that some misunderstanding is resolved. We thank Gajdosik for his remarks and constructive contribution.

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